ROBOTICS

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Ultrasonic vision

FOR A ROBOT TO EXHIBIT EVEN A modicum of intelligence, it needs some type of feedback mechanism between the "thinking" part and the "doing" part. Without some type of feedback, the "thinker" can't adjust the actions of the "doer" in response to changes in its environment.

The most useful form of feedback for human beings is visual. Machine vision, however, is limited by current technology in its ability to resolve details and in its ability to estimate distances.

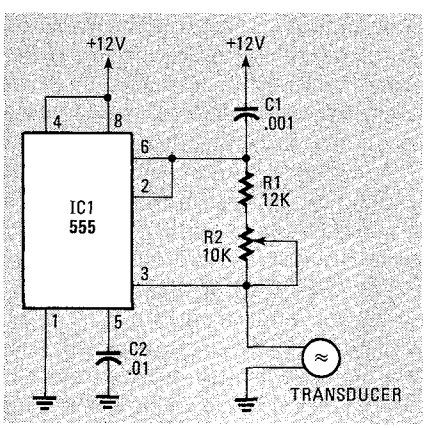

FIG. 1

There are several dozen companies now selling machine-vision systems to industrial manufacturers. Those systems are generally used to inspect finished goods. There are a few companies selling devices that will help a mobile robot get around in a cluttered room. With that type of vision, a robot can see what it is gripping, where it is going and where it has been.

Human beings have a crude, built-in distance measuring system that makes use of the eyes as well as stored knowledge of how

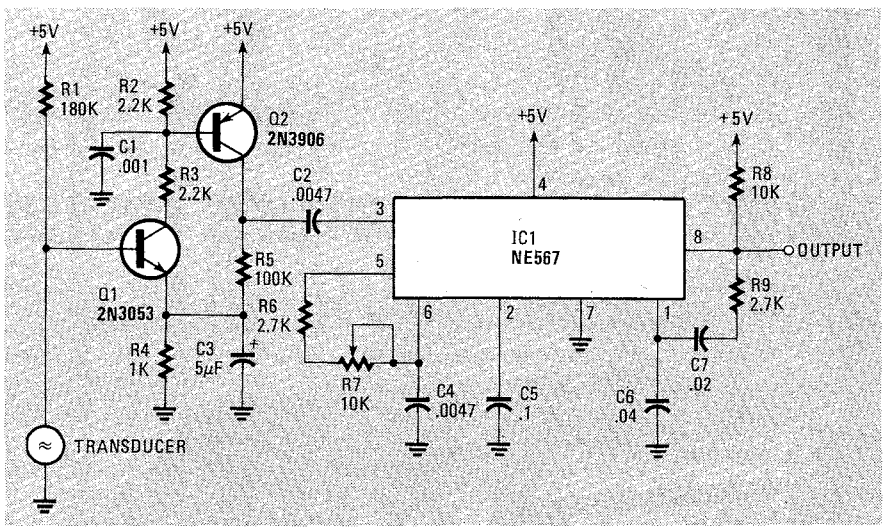

FIG. 2

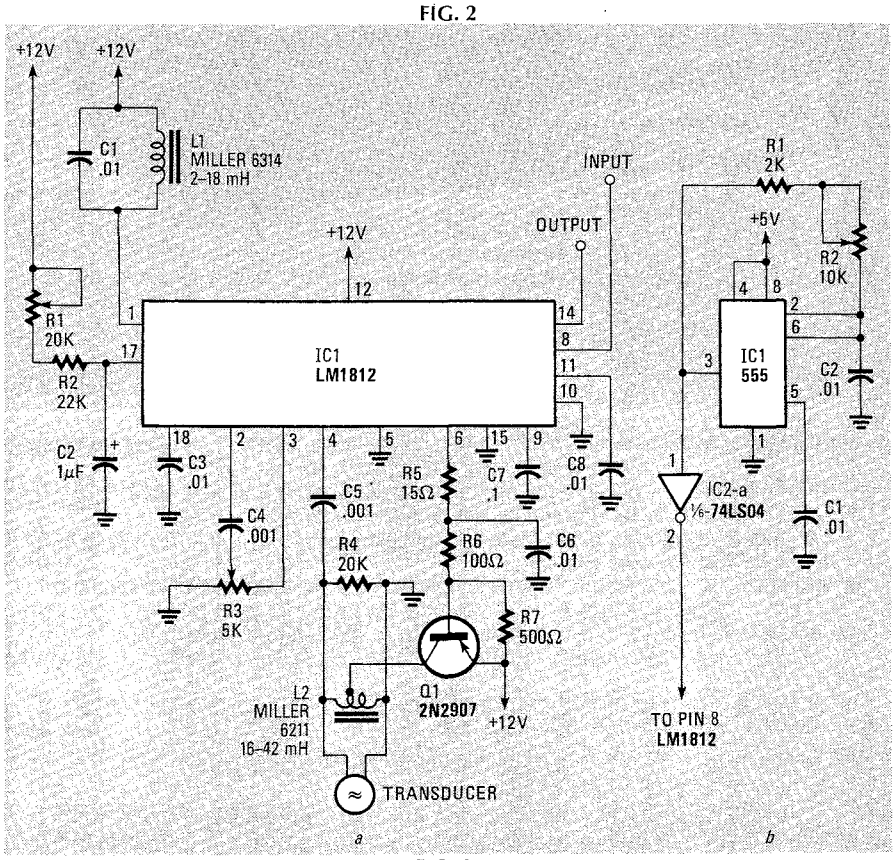

FIG. 3

an object looks at different distances. We then compare the known image to the one we are presently encountering and *voilà*—we obtain a rough estimate of the object's distance. That is the method used by systems that inspect parts on a finished-goods assembly line. We could apply that method to a robot system, but that would require auto-focusing lenses and complex image-analysis algorithms in the controlling electronics. However, there is a simpler and more economical way to obtain distance information: *ultrasonic ranging*. That method is frequently more accurate than light-wave systems.

Ultrasonics theory

In a typical ultrasonic ranging application, an ultrasonic transmitter starts a timer as it emits a short burst of 40-kHz sound waves through its transducer. Those sound waves spread out as they travel through free air. When they strike an object in their path, some of the sound is deflected back toward the transducer, which now acts as a receiving device, like a conventional audio microphone. The received sound waves are sent to a discriminator circuit that stops the timer.

The value in the timer is proportional to the length of time it took the sound waves to travel to the object and return to the origin. We can determine the distance (D) from the period measured by the timer (T) by using the classic formula, D = V/T. V here stands for velocity, and is simply the velocity of sound waves in air, about 13,080 inches per second. Basically that's all that's needed to measure distance. So let's look at some practical implementations of both transmitters and receivers.

Ultrasonic circuits

A simple 40-kHz transmitter is shown in Fig. 1. The 555 is a very inexpensive eight-pin timer IC configured as an astable multivibrator oscillating at a frequency of 40 kHz. (That frequency can be adjusted by potentiometer R2.) With a twelve-volt supply, the 555's output will swing about ten volts, which should be enough to drive common transducers. Any 40-kHz oscillator could be substituted for the circuit shown in Fig. 1. In fact, it would be quite simple to generate a 40-kHz signal with a computer, and drive a transducer with that signal through an open-collector TTL gate (such as a 7406).

The receiver portion of the system is only a little more complex. In the circuit shown in Fig. 2, the received signal is amplified by a discrete transistor amplifier, and then applied to a tone-decoder NE567. That IC, a phase-locked-loop contains its own internal oscillator that must be adjusted to match the transmit frequency. The NE567 has a comparator that will send the output high when it detects an incoming signal equal in frequency to its internal oscillator.

The circuit shown in Fig. 3-*a* uses a single IC specially developed by National for use as an ultrasonic transceiver. Using such a device allows you to use a single transducer for both transmit and re-

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ceive functions. In addition, the same tuned circuit is used for both transmitting and receiving, so you don't have to worry about frequency mis-matching due to component drift.

Transmission is initiated by applying a logic "1" to pin 8 of the LM1812. The receiver will be disabled, and pin 14 will be low. To receive, pin 8 is simply grounded. Pin 14 will go high after the circuit receives an echo of the signal.

The time between initiating transmission and pin 14's going high is then equal to the time required to travel from the transmitter to the object and back. So to obtain the distance to the object, that time would be halved and plugged into the formula $D = V/T$ ($V = 13{,}080$). The circuit shown in Fig. 3-*a* has a range from 4 inches to about 6 feet. By adding the 555 circuit shown in Fig. 3-*b*, the low end of the range may be decreased to 3 inches, and the high end increased to 20 feet. Potentiometer R2 should again be adjusted to a frequency of 40 kHz.

That circuit is so simple and so inexpensive that you could build several for one robot.

Polaroid's ultrasonics

Polaroid Corporation has been using ultrasonic ranging in cameras such as the *SX-70* for some time now. Distance information obtained through ultrasonics is used to focus the camera's main lens automatically. The transducer used has a larger diameter and is slimmer than the type usually found in electronics surplus stores. Several years ago Polaroid packaged the electronics from their cameras along with a good tutorial manual, as well as an interesting experimenter's board. The package is called the "Polaroid Ultrasonic Ranging System Designer's Kit," and is available for $165 from the Polaroid Ultrasonics Components Group (Polaroid Corp., 119 Windsor Street, Cambridge, MA 02139). It comes with a special interface that displays distance information on an LED readout. **R-E**